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AIR UNIVERSITY

IMPROVING DENTAL HEALTH OF DOD RELATED
PERSONS ASSIGNED TO OKINAWA BY USING
FLUORIDATED SALT IN LIEU OF WATER FLUORIDATION
A COMPARATIVE ANALYSIS

by

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Preface

This research is an outgrowth of my tour as Deputy of the 18th Civil Engineer Squadron and 18th Civil Engineer Group at Kadena Air Base in Okinawa (1994-1997). During this time, the 18th Medical Group (MDG) set fluoridating the base water supply as a goal to prevent dental caries – a noble and desirable goal.

Fluoridating the base water system requires purchasing tons of a hazardous chemical annually and subsequently discharging it to the environment. Unfortunately, both of these actions (increasing purchases and discharges of hazardous chemicals in to the environment) conflict with laws such as the Pollution Prevention Act and Resource Conservation and Recovery Act. It also conflicts with Executive Orders 12856 and 12873; numerous DOD regulations (e.g., DODD 4715.1, DODI 4715.4, and DODI 4715.6); AF regulations (e.g., AFI 32-7080 and AFRD 32-70) and AF policies (i.e., AF Pollution Prevention Strategy).

A driving factor for this paper was to solve the dilemma of reducing dental caries and improving oral health while simultaneously complying with regulations and laws. Several alternatives were considered. All solutions, including the fluoridated salt alternative investigated here, had been rejected by 18 MDG without meaningful evaluation. The reason was that only water fluoridation met their goal of fluoridating the base water system.

This paper is an attempt to accurately compare the effectiveness and efficiency of providing supplemental fluoride via salt to that of fluoridated water. My thesis is that selling fluoridated salt in the Commissaries is a more efficient, more effective, and less costly alternative than water fluoridation for improving the oral health of our military, civilian and dependent populations. In addition, it can be implemented in compliance with all laws, regulations, and policies.

At the risk of being verbose, let me share a few things learned during this research (and I learned more about fluoridation than I ever cared to know). First, it is my opinion that advocates for and against water fluoridation will mislead, parse information, communicate half-truths, and engage in propaganda and “spin” the envy of any political party. Regretfully, this is even true for prestigious health professionals and their associated organizations. For example, one prestigious organization seeking to disprove fluoride may increase hip fractures cited a source claiming no significant increase overall was found. The fact that this same source found a statistically significant increase for males was never mentioned.

The literature is also replete with studies that absolutely fail to meet generally accepted scientific rigor (i.e., blind studies with control groups). This leads to many biased studies. The point being made is that fluoridation is such a political and emotional issue that it leads to biased studies and papers—even for those attempting to avoid bias.

Acknowledgments

I wish to acknowledge the assistance of those who helped make this paper possible. Thanks first go to my advisor, Major Terry Bentley, for believing this subject was worthy of investigation and seeing its potential value. His insights, support and encouragement were essential to the success of this effort. Thanks also go to Dr. Gray for her assistance in helping me overcome writer's block. The data provided by Yvonne Gonsalves (Melbourne's fluoridation data) and Dawn Barker (Kadena housing statistics) plus their willingness to answer questions ensured a solid foundation for this effort. Last, and most importantly, I am truly grateful for the support of my wife, Jenny Stokes, and my children, Jenna and Katie Stokes, who understood that Daddy was very busy working on his research paper and could not come out and play, or at least not very often.

Abstract

BACKGROUND: Good oral health is vital to U.S. military and DOD related personnel. Supplemental fluoride may be an effective method of improving oral health by reducing dental caries. Water and salt fluoridation were evaluated as methods to provide mass supplemental fluoride to DOD related personnel stationed at Okinawa. **METHOD:** The two methods were compared with respect to effectiveness, dose control, delivery effectiveness in targeting receptors, costs, and other factors such as environmental and health issues. **RESULTS:** Approximately 14 percent of the DOD related population consumed bottled water. Water fluoridation would benefit 3,700 full-time-equivalent (FTE) children and 8,310 FTE adults and prevent 370 and 500 caries annually at a cost of \$55.5-\$79 per carie avoided. Annual operating and life cycle costs for the Air Force to fluoridate Kadena water were estimated at \$48,250 and \$68,800 respectively. Fluoridated salt would benefit 6,630 FTE children and 23,780 FTE adults and prevent 660 and 1,430 caries annually at a cost of \$2.50 per carie avoided. Air Force annual operating and life cycle costs for salt fluoridation were estimated at \$100 annually. Salt fluoridation complies with all environmental laws, DOD regulations, and policies and may result in more consistent fluoride doses.. It avoids injecting 21,600 pounds of hazardous material in to the Okinawan environment as occurs with water fluoridation. **CONCLUSION:** Fluoridated salt is the most effective, most efficient, safest, and most economical method of providing supplemental fluoride to DOD personnel on Okinawa.

Chapter 1

Importance Of Good Dental Health

Good oral health has long been recognized as important to everyone. Poor oral health can lead to painful teeth and gum diseases, and unsightly physical appearances. It can also lead to costly and time-consuming dental work.

For military members, good oral health is more than desirable for the military – it is critical. This has been recognized for decades and in fact, those military members who are believed at potential risk for dental emergencies are placed in class 3 status. Military members on class 3 status are non-deployable.

Impact of Dental Health on Wartime Readiness

Readiness is the mainstay of our forces. As the size of the military force continues to reduce, readiness will become an even more important factor. If a military member can not deploy, regardless of the reason, his or her unit will presumably suffer. Rodden et al. state that “Military personnel who must leave their place of duty because of an unexpected emergency reduce the strength and effectiveness of their units.”¹

Military members placed on class 3 status for dental reasons are non-deployable. This can be a significant problem. Major Charles Douglass demonstrated this when he wrote,

...when I was the commander of the Security Forces Unit at Robins I was responsible for the deployment status of my forces. The biggest problem I had keeping people ready for deployment was Cat III dentals. Every deployment that I was tasked with of any size, I would lose at least one person to a Cat III classification.²

The importance of dental readiness can not be understated. Col. Keller wrote, “It is well documented that dental casualties during conflict have accounted for a significant amount of lost duty time of vital personnel.”³

The frequency of dental problems has been the subject of numerous studies. Rodden et al. reports an annual incident rate of 57 incidents per thousand for Marines and Grover et al. reports 258 dental emergencies per thousand for Army recruits.⁴ According to Keller, one study found an annual rate of 167 dental emergencies per thousand troops resulting in 121.5 lost duty days per thousand troops annually.⁵ Even more telling, Rodden reports that “Seven percent of medical evacuations from U.S. Navy ships and submarines have been reported to be due to non-injury-related dental problems.”⁶

The above indicates that dental problems can have a serious impact on meeting mission requirements. Clearly preventing these types of emergencies carries a high desirability factor. The avoidance of lost man-days and having key personnel ready and available for deployment is a strong incentive. A reduced workload for dental and medical staffs is an additional benefit.

All dental related emergencies can not be prevented by any one public health initiative. Examples of non-preventable dental emergencies include accidents and battle injuries. There are, however, many preventable dental emergencies. Most dental emergencies caused by caries are considered preventable.

Preventing dental caries has several significant benefits. These include avoiding lost man-days, reduced work loads for dental staffs, cost savings, and reducing the probability of military members becoming non-deployable due to class 3 status. A benefit to preventing caries is that decay can start or continue under existing fillings but only occurs on the outside of sound teeth. A filling with decay underneath must be replaced and may lead to more serious dental problems (e.g., root canals or even loss of the tooth). Another benefit is avoiding barodontalgia. Barodontalgia can be caused by an imperfect restoration.⁷ For example, a small gaseous bubble may become trapped which then expands in low-pressure situations such as high altitudes. There the bubble can cause severe pain and debilitate pilots, crewmembers and other personnel.

There may also be significant cost savings to be gained by implementing cost effective preventive dental health programs. An estimated \$4.5 billion was spent on amalgam restorations in 1990.⁸ In 1995, the Kadena Dental Clinic performed approximately \$750,000 worth of restorative work.⁹ Reducing dental caries by even 15 percent could save the Clinic (and the Air Force) approximately \$110,000 dollars annually. More importantly this could free up approximately one man-year of a dentist's time by preventing almost 2,200 dental caries per year (assuming the cost to restore each carie is \$50 and that all restorative work for the Clinic involved caries).

Notes

¹ Captain Jeffrey W. Rodden and LCDR John W. Simecek, "Dental Emergency Visits of Marine Corps Personnel," *Military Medicine* 160, no. 11 (November 1995): 555.

² Major Charles Douglass, *Personal Communication*. February 1999.

³ Colonel David L. Keller, "Reduction of Dental Emergencies Through Dental Readiness," *Military Medicine*, 153, no. 10 (October 1988): 498.

Notes

⁴ Captain Jeffrey W. Rodden and LCDR John W. Simecek, "Dental Emergency Visits of Marine Corps Personnel," *Military Medicine* 160, no. 11 (November 1995): 555.

⁵ Colonel David L. Keller, "Reduction of Dental Emergencies Through Dental Readiness," *Military Medicine*, 153, no. 10 (October 1988): 498.

⁶ Captain Jeffrey W. Rodden and LCDR John W. Simecek, "Dental Emergency Visits of Marine Corps Personnel," *Military Medicine* 160, no. 11 (November 1995): 555.

⁷ R. E. Holowatyj, "Barodontalgia Among Flyers: a Review of Seven Cases," *Journal Canadian Dental Association* 62, no. 7 (July 1996): 578-84 (Pubmed abstract).

⁸ U.S. Department of Health and Human Services, Reprint from MMWR, May 29, 1992, Vol.41, No.21, PP.372-5,381.

⁹ Colonel Canning and Mr. Noorda, "Talking Paper on Fluoridation of Kadena AB Drinking Water," 26 Apr 1995.

Chapter 2

Dental Caries

The previous chapter discussed the importance of good oral health. It also identified why good oral health is vital for our military members—especially our deployable members. This chapter provides background information on dental carie distributions and prevention of dental caries through the use of fluoride. It is written at the layman level but many dental professionals may find information previously unknown to them.

Dental caries resulting from tooth decay are a preventable form of dental disease. There are many causes of tooth decay. Tooth decay can, however, be significantly reduced through good oral health activities. This approach requires constant and proper practice. Brushing teeth daily may aid in reducing caries but improper or infrequent brushing may still allow some preventable caries to develop. The propensity to develop dental caries is related to genetics and not all caries can not be prevented.

Caries development by age group

Dental carie formation rates are not consistent throughout a lifetime. Children have deciduous teeth and may have more or less teeth during certain ages. Accidents may reduce the total number of teeth thus reducing the number of surfaces having the opportunity to decay. In addition, teeth that already have restorations have fewer surfaces available for decay. These are only a few of many reasons.

Table 1. is based upon data from the World Health Organization web site and shows decayed, missing and filled teeth (DMFT) rates for United States residents by age. This data is used through out this study for general population statistics.

Table 1. Decay Rates by Age Group

Age Group	DMFT	Annual decay rates or
3 years	0.4*	n.c.
6 years	1.8*	n.c.
12 years	1.4	n.c.
15 years	2.6	0.4
18 years	4.5	0.63
34-44 years (39**)	13.3	0.42
65+ years (74**)	22.1	0.25

Source: www.whocollab.odont.lu.se/amro/usa/data/usacar.html

* —indicates decayed missing and filled deciduous teeth

** —weighted average age based upon 1990 US population statistics.

n.c.—not calculated or not meaningful

Prevention of Dental Caries

Back in the 1920's it was noted that persons whose teeth had brownish stains and discoloration seemed more resistant to tooth decay. Researchers subsequently discovered that these stains and discolored (mottled) teeth were due to excess fluoride consumption. This condition, now known as fluorosis, was linked to consumption of water with high fluoride content. This led to the realization that fluoride, in addition to causing mottling of teeth, could also reduce tooth decay. It may also heal minor caries.

How fluoride Works

There is general agreement that it is unclear exactly how fluoride works to prevent dental caries. That is where the agreement ends. It has been proposed that fluoride has both topical and systemic effects.

The exact causes of tooth decay are complex and poorly understood. Acid may be the primary cause of tooth decay. Sources of acid include food, beverages, and conversion of sugars and carbohydrates into various acids by bacteria.

Fluoride is believed to have both topical and systemic effects and to primarily prevent decay in three ways. It may be incorporated into the enamel of developing teeth. The fluoride may also be absorbed through the enamel where it assists in restoring and hardening of enamel already suffering mild decay. Fluoride may also reduce the amount of acid in the saliva due to its effects upon bacteria.

For decades, the systemic benefits were believed to be obtained by ingesting fluoride in low doses during the teeth forming or post-eruptive years. Fluoride consumed during this time becomes part of tooth enamel. This was believed to cause tooth enamel to be more resistant to acids and thus more resistant to decay. The popularity of this theory is declining as “Investigators have failed to show a consistent correlation between anticaries activity and the specific amounts of fluoride incorporated into enamel.”¹ Weakening this theory is a study that found use of prenatal fluoride tablets provided no beneficial effect for children during their first five years.² Another potential problem with this theory is that the fluoride ions do not provide a contiguous layer of protection. Thus decay can work its way around the fluoride ion and even take out the support behind the fluoride.

Ingested fluoride is still believed by many to be beneficial.³ This belief is based upon the theory that ingested fluoride becomes part of the body fluid and recycles itself in to the saliva. There the fluoride constantly bathes the tooth's surface (see topical fluoride benefits below). Fluoride in the saliva also fights the bacteria or the bacteria's ability to produce acids. Examples of sources of low level fluoride for this mechanism are water borne fluoride, fluoride tablets, and fluoridated salt.

Direct or topical application of fluoride prevents decay and reduces dental caries in two ways. The first is by applying high concentrations of fluoride to the exterior of the tooth. There the fluoride appears to re-mineralize or assist in re-mineralizing the tooth surface.⁴ Two common examples of high concentration topical applications are fluoridated toothpaste and fluoride rinses. The second method whereby topical fluoride provides benefits is that some of the fluoride is swallowed or lingers in the mouth and thus provides the benefits previously described for ingested fluoride.

Fluoride Recommendations

The literature is replete with references to "optimal levels" and "optimum intakes" of fluoride. There does not, however, appear to be a solid consensus on what the optimal range is or even on the definition of optimal. The most common inference is that optimal fluoride doses represent a trade off between dental fluorosis and dental caries.

There is not universal agreement among health professionals and scientists with respect to fluoride dosages. Opinions vary as to the proper age to begin fluoride supplements and at what age (if ever) fluoride supplements should end.

Recommended doses generally vary based upon the age of the recipient and the concentration of fluoride in the recipient's drinking water. Table 2. shows some of the

recommendations and identifies the recommending body. In some cases recommendations are inconsistent within organizations.

Table 2. Fluoride Recommendations

Recommendations of American Dental Association, American Pediatric, American Dietetic Association, Canadian Pediatric Association			
Age	Concentration of fluoride in the drinking water (PPM)		
	< 0.3	0.3-0.6	> 0.6
0—0.5 years	nrg	nrg	nrg
0.5—3 years	0.25	0	0
3—6 years	0.5	0.25	0
6—16 years	1.0	0.5	0
+16 years	nrg	nrg	nrg
Note: ADA recommends fluoride for all ages but also endorsed the above			
Recommendations of Canadian Dental Association			
0—3 years	0	0	0
3—5 years (1)	0.25	0	0
3—5 years (2)	0.5	0	0
Canadian Fluoride Conference—Consensus of Scientific Experts (Nov 1997) (3)			
0—0.5 years	0	0	0
0.5—3 years	0.25	0	0
3—6 years	0.5	0	0
6—16 years	1.0	0	0
+16 years	nrg	nrg	nrg

Sources: (American Dietetic Association) www.eatright.org/fluoridetable.html, and www.interlog.com/~hardyl/results/res_cont.html.

- (1) Doses are in mg of fluoride per day.
 - (2) With regular use of fluoridated toothpaste.
 - (3) Without regular use of fluoridated toothpaste.
 - (4) Assumes the 0.03 PPM is a typographical error and should be 0.3 PPM.
- Nrg—no recommendation given for this age.

As Table 2. shows, recommended levels of supplemental fluoride vary considerably (note: artificially fluoridated water is considered a form of supplemental fluoride). All of the recommendations shown in Table 2 end on or about 16 years of age. The American Dental Association (ADA) recommends fluoride supplements for everyone living in areas

with water supplies that are suboptimally fluoridated. This appears to conflict with their endorsed recommendation shown in Table 2. The American Academy of Physicians position is that “Dietary fluoride supplements should be considered for children from ages six months through 16 years when drinking water levels are suboptimal.”⁵

The recommendations in Table 2. are based upon the age of the recipients and vary with water concentration. This approach does not account for differing sizes and body weights within age groups. These vary greatly over a 10-year age range for children of mixed genders. To overcome this limitation, some scientists and health professionals have sought to determine doses based upon body weight.

Levy et al. discusses optimum fluoride intake based upon body weight (bw) and reviews several citations in the literature.⁶ The literature review by Levy et al. suggests that fluoride intakes prior to two years of age escalates the risk of fluorosis and that doses as low as 0.03 to 0.04 mg Fl/kg bw may be connected to fluorosis in permanent dentition. Levy et al. eventually settles on an “optimum” range of 0.05 to 0.07 mg Fl/kg bw.

Effectiveness of Fluoride

The effectiveness of supplemental fluoride is impossible to quantify. Some reasons are: variability of fluoride levels, a lack of studies involving older age groups, results vary by nation, declining carie rates in both fluoridated and non-fluoridated communities, and the wide variability in effectiveness seen in similar studies. Another reason is that many studies were not scientifically rigorous (i.e., a blind study with a control group) and therefore are potentially biased

Attempts to identify carie reduction rates almost always resort to studies external to the USA. Table 3. shows the results of some of these reviews. Lewis et al. notes that

Newbrun left out several studies from Canada. The omitted studies show reductions in the 8-56 percent range with reductions of 20 percent or less seen in seven of 13 studies.

A review by Lewis et al. reported on efforts by other reviewers. Lewis cites a 1982 study that found 40-50 percent reductions. A 1982 review by Newbrun encompassing the USA, Australia, Britain, Canada, Ireland and New Zealand is often cited. This review concluded that fluoridation could reduce caries by 30-60 percent in deciduous teeth, 20-40 percent in mixed teeth, 15-35 percent less for ages 14-17 and that the 15-35 percent reduction would also apply to adults and seniors.⁷

Table 3. Reviews of Carie Reduction Rates

Category	Percent Reduction Claimed	Inclusive Study dates	# of different Countries used in review
deciduous dentition	30—60	1950—1987	6
mixed dentition (ages 8—12)	20—40		
Adolescents (ages 14—17)	15—35		
Adults and Seniors	15—35*		

Primary teeth	40—50	1945—1978	20
Permanent teeth	50—60		

Source: E. Newbrun. “Effectiveness of water fluoridation.” *Journal of Public Health Dentistry* 49, (Spec Iss): 279-89.

*—Newbrun presumes this range also applies to this age group

There are significant flaws in Newbrun’s review and conclusions. Few of the studies cited are scientifically rigorous. The trend shown in Table 4 of decreasing caries over time is not taken in to account. Newbrun also states that recent decay reduction rates for

five year-olds, seven year-olds, and other age groups in the USA are 39, 32, and 18-22 percent respectively. These rates are all at the bottom of the ranges he previously stated.

Table 4. DMFT Changes Over Time

RURAL ALBERTA's Decayed Missing Filled Teeth (DMFT) RATES 1977/78 to 1984/85					
School or Village	Year Fluoridated	Water Fl PPM	DMFT 1977/78	DMFT 1977/78	Percent decay reduced between years
Albert Lacombe	1962	1.00	3.46	2.97	14
Barrhead	1964	1.00	6.59	2.42	63
Bertha Kennedy	1962	1.00	5.31	2.47	53
Bon Accord	Natural	0.52	3.96	3.51	11
Busby	Well water	0.19	7.12	4.0	44
Dunstable	Well water	0.19	4.80	1.50	69
Fawcett	Well water	0.27	4.99	3.95	21
Gibbons	1976	1.00	5.06	3.65	28
Guthrie	1967	1.00	5.35	2.39	55
Legal	1989	1.00	5.53	4.14	25
Leo Nickerson	1962	1.00	4.23	3.47	18
Newbrook	Natural	0.55	6.68	4.57	32
Radway	Natural	0.12	5.52	6.00	+9
Redwater	1964	1.00	4.94	2.81	43
Robert Rundle	1962	1.00	4.53	2.51	45
Sturgeon Heights	1962	1.00	4.63	2.85	38
Thorhild	Natural	0.12	5.12	4.41	14
Vimy	Well water	1.41	4.42	2.46	44
Vital Grandin	1962	1.00	4.30	2.40	44

Source: <http://www.cadvision.com/fluoride/caries3.htm>. The Table is an adaptation of Canadian data from the Report of the Second Alberta Dental Health Survey.

Data in Table 4 is shown graphically in Figure 1. The intercept, slope and correlation coefficient are 22 percent, 16 percent per PPM of fluoride, and 0.32. The average reduction is 34 percent with a standard deviation of 20 percent. This data shows a trend

toward reduced caries (with one exception) over time for constant fluoride levels. This suggests that absent any fluoride in the water, a 22 percent decrease in DMFTs would have been expected. These trends suggest that the effectiveness of fluoride would be at the lower end of Newbrun's rates. For simplicity, fluoride from any source will be presumed to reduce decay by 25 percent for those between six months and 16 years of age and by 15 percent for those over 16 years of age.

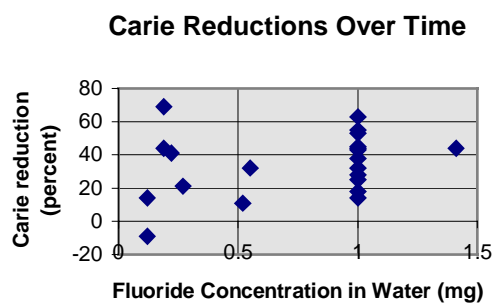


Figure 1. Carie Reductions Over Time

Notes

¹ Review of Fluoride, Benefits and Risks, Report of AD HOC Subcommittee on Fluoride February 1991, page 7.

² D. H. Leverett et al., "Randomized clinical trial of the effect of prenatal fluoride supplements in preventing dental caries," *Caries Research* 31, no. 3 (May-June 1997): 174-9.

³ Policy Statement, *American Academy of Pediatrics* 77, no. 5 (May 1989), available from <http://www.aap.org/policy/217.html>.

⁴ Review of Fluoride, Benefits and Risks, Report of AD HOC Subcommittee on Fluoride February 1991, p 7.

⁵ Compendium of AAFP Positions on Selected Health Issues, American Academy of Family Physicians. On-line. Internet. Available from www.aafp.org/policy/50.html.

⁶ S. M. Levy et al., "Infants' Fluoride Intake from Drinking Water Alone, and from Water Added to Formula, Beverages, and Food", *Journal Dental Research* 74, no. 7 (July 1995): 1399-1407.

⁷ E. Newbrun. "Effectiveness of water fluoridation." *Journal of Public Health Dentistry* 49, (Spec Iss): 279

Chapter 3

Comparison Criteria and Methodology

The previous chapters discussed the importance of preventing dental caries, how caries negatively impact military readiness, and identified supplemental fluoride as method of potentially reducing dental caries. There are several viable alternatives for providing supplemental fluoride including water fluoridation, fluoridated salt, fluoridated milk, and fluoride tablets. The last two methods, however, are of limited use. Milk consumption tends to be greatest in early childhood and to decrease with age. This would cause fluoride intake to decrease with age, the opposite of the desired trend. Fluoride tablets are effective but require that the user remember to take the tablets. This reduces their effectiveness as a mass public health effort. This leaves fluoride enriched salt and water fluoridation as viable alternatives.

The viability of these two alternatives is already proven. They are the two most frequently used methods of providing fluoride supplements throughout the world with fluoridation of water supplying 210 million people and salt supplying 50 million people.¹ Both methods are probably more widely used today than these numbers indicate.

Comparison Methodology

To compare water fluoridation to salt fluoridation will require an analysis of the DOD population and its geographical dispersion. Factors that will be considered for each system are:

carie prevention effectiveness, accuracy of dose, effectiveness in delivering the dose to receptors, cost of startup, cost of operation, and environmental factors.

The Geographical Setting

There are 11 significant U.S. military installations on the island of Okinawa listed in the Directory of U.S. Military Bases Worldwide.² These installations include Camp Smedley D. Butler, MCB, Camp Courtney, Camp Foster, Camp Hansen, Camp Kinser, Camp Lester, Camp Schwab, Futenma, Marine Corps Air Station, Kadena Air Base, Kadena Naval Air Facility (Camp Shields) and Torii Station.

The Air Force (AF) has responsibility for all military family housing (MFH) services on Okinawa. The AF maintains approximately 8,120 military family quarters located in 19 different housing areas. At any one time there are approximately 100 to 300 vacant units due to renovation, radon problems, or change of occupancy maintenance. Waiting times for housing units range from 3-18 months depending upon location, housing preferences (single family, duplex/multiplex, or tower apartment) and rank. The exception is for families whose sponsor occupies a key and essential position (e.g., group commanders, wing commanders, etc.). These families move directly on base with no waiting.

Population

The total US population on Okinawa is close to 80,000.³ The total Department of Defense related population fluctuates but is generally in the range of 55,000-56,000 personnel. In February 1997, the DOD related population on Okinawa consisted of approximately 55,730 personnel including 27,260 active duty, 27,000 dependents, and 1,470 civil service employees.⁴

Table 5 provides a breakout of personnel by category. According to July 1998 manpower figures, Kadena had 6,767 active duty, 350 civil service, and 9,618 dependents assigned.⁵

Table 5. DOD Related Population on Okinawa

Service	Active Duty	Dependents	Civilians
Marines	16,900	9,300	460
Navy	2,500	2,500	240
Air Force	7,000	13,700	630
Army	860	1,500	140
TOTALS	27,260	27,000	1,470

Source: 1st Lt Laura Koury, Kadena Public Affairs, July 1998

According to the Department of Defense Dependents School (DODDS) there were 9,677 students (this excludes 201 tuition paying students and an unknown number of students that attend local schools) in June 1995.⁶ Assuming school aged children are linearly distributed between six and 18 years of age suggests there are approximately 806 children per age group. This equates to approximately 14,500 total DOD related children under 18 years of age.

The consensus of the ADA, American Pediatric Association, American Dietetic Association, and Canadian Pediatric Association is that children between the ages of six months and 16 years should receive supplemental fluoride. There are approximately 12,500 children in this age range.

Taking the 1997 population and subtracting out the 12,500 children that are the recommended receptors leaves an additional 43,230 persons. Thus the total Department of Defense related population on Okinawa can be grouped as follows: 400 infants under six months of age, 12,500 children between six months and 16 years of age, 1,600 children between 17 and 18 years of age, and 41,200 adults over 18 years of age.

In February 1999 there were 13,255 persons living in MFH considered part of Kadena.⁷ In addition, there were 1,895 unaccompanied personnel living in dormitories or other quarters. Thus

there were a total of 15,150 persons living in housing considered part of Kadena housing. A breakout by service is shown in Table 6.

Table 6. Military Population Living in Kadena Housing

Kadena AB	MFH	Sponsors	Dependent	Total
Service	units occupied	Population	Population	Population
Air Force	2964	3215	7142	10357
army	220	231	537	768
Navy	195	205	440	645
Marine	263	273	699	972
DECA	8	8	15	23
AAFES	24	24	80	104
DODDS	103	114	220	334
Other	16	16	36	52
TOTAL (MFH)	3793	4086	9169	13255
Unaccompanied		1895		1895
TOTAL Population Living on Kadena				15150

Source: 28 February 1999 Marine Monthly Report.

The total population of children can be approximated by assuming that the number of single parent families equals the number of families with older dependents (e.g., parents, grandparents, etc.). Based upon this assumption there are approximately 5,670 children on Kadena. This is in line with Norda's estimate of 5,727 total children in Kadena housing in 1995.⁸

Dose Control

To evaluate the consistency of doses of any supplement or medication requires determination of an appropriate dose and comparison to consumed quantities. The lower the variability the better and tighter the quantity focuses on the recommended dosage for each age group without exceeding maximum dosages the better.

Delivery Effectiveness

The effectiveness will depend upon the availability of the supplement as well as the propensity to consume the supplement. Availability will be evaluated based upon geographical locations and propensity to consume will be based upon general tendencies for groups. Heroic efforts will not be considered (i.e., purchasing fluoridated salt via mail or filling bottles of water from the fluoridated source will be ignored). This is justified as fluoride tablets are available.

Other Considerations

Several other factors must be considered for completeness. These factors are not dealt with in depth but deserve a few words. These factors include: compliance with environmental laws, regulations and policies; health-related concerns, and force protection issues.

Notes

¹ World Health Organization Press Release, 15 February 1994.

² William R. Evinger, *Directory of U.S. Military Bases Worldwide*, 3rd ed. (Oryx Press, 1998) 268-273

³ Kadena Public Affairs, On-line. Internet. Available from www.kadena.af.mil/current/18pa/welcome.htm

⁴ 1st Lt Laura Koury, Kadena Public Affairs, Personal Email, 27 Jul 1998.

⁵ Personal email. SSgt Orville Desjarlais, Kadena Public Affairs dated 29 July 1998

⁶ Notes, Conversation with DODDS personnel, 1996.

⁷ Marine Monthly Report on Base, 28 February 1999, provided by Dawn Barker of Kadena Housing Office.

⁸ Jeff Norda, Personal Notes referencing a 1995 Marine on Base Housing Report, 1996.

Chapter 4

Water Fluoridation

Adding a compound containing fluoride to municipal water systems (water fluoridation) is the method currently used throughout the USA. There are approximately 144 million Americans served by water systems that have naturally or artificially fluoridated water.¹ “Countries and geographic regions with extensive fluoridation include the U.S., Australia, Brazil, Canada, Hong Kong, Malaysia, U.K. and Russia.”²

The process of fluoridating water involves addition of a fluoride-containing chemical that releases fluoride ions in to the water. The three most commonly used chemicals are: sodium fluoride, hydrofluosilicic acid and sodium silicofluoride.³

Water fluoridation sounds simple but in reality is quite complex. One complicating factor is that many fluoride compounds are relatively insoluble in water.⁴ Impurities in the water such as calcium or magnesium react with the fluoride ions and precipitate out. Liquid sources such as hydrofluosilicic acid must be treated with special care for employee protection. The Centers for Disease Control has a 99-page manual for water plant operators involved in water fluoridation.

Another factor is that accurate and reliable systems are critical. Few benefits are obtained if fluoride concentrations are too low while excess fluoride can violate federal water standards, have serious negative impacts on long-term health, cause acute fluoride poisoning or even death.

Effectiveness

The effectiveness of water fluoridation was previously discussed under fluoridation. For the purposes of this paper expected carie reduction rates are 25 percent for those under 16 years of age and 15 percent for all others.

Dose Control

The dose of fluoride obtained from drinking water depends primarily upon two factors: volume of water consumed and concentration of fluoride in the water. Water consumption varies with activity level and food consumption habits. Fluoride concentrations vary for several reasons including: differing target concentrations, water flow variances, stratification, inconsistent feed chemical concentrations, failure to calibrate equipment and equipment malfunctions. Target concentrations for water fluoridation range from 0.7-1.2 parts per million (PPM) of fluoride ion.⁵

The consistency of fluoride concentrations for artificial fluoridation systems was evaluated based upon data from the city of Melbourne, Florida. Melbourne's customer base consists of approximately 140,000 customers and includes Patrick Air Force Base. Melbourne was selected as it tested concentrations daily and agreed to provide data. The system clearly demonstrated real world events as equipment failure caused the system to be turned off for part of the year. Fluoride concentration data is shown in Table 7.

This data shows that fluoride ion levels ranged 0-0.995 PPM during 1998 and from 0.657-0.995 (a 50 percent variation) while the system was operational. The population did not have access to fluoridated water for 139 days (38 percent of the year) due to equipment failure.

Data on daily water consumption rates are not readily available. Water consumption rates for adults are shown in Table 8.⁶ No explanation was given for the wide range.

Table 7. Fluoride Concentrations for City of Melbourne (1998)

Month	Mean	Median	Minimum	Maximum	Std Dev
Jan	0.770	0.779	0.628	0.916	0.070
Feb	0.786	0.794	0.676	0.939	0.063
Mar	0.771	0.769	0.692	0.950	0.049
Apr	0.809	0.814	0.692	0.991	0.076
May	0.811	0.801	0.703	0.995	0.063
Jun	0.770	0.773	0.657	0.887	0.0542
Jul*	0.784	0.783	0.693	0.864	0.038
Aug*	off	off	off	off	off
Sep*	off	off	off	off	off
Oct*	off	off	off	off	off
Nov*	off	off	off	off	off
Dec*	0.717	0.755	0.142	0.790	0.142

Source: Melbourne water system, Melbourne Florida

*System turned off on 7/26/98 due to equipment failure. System restored on 12/12/98

Many activities influence water consumption. For example, athletes tend to drink more water than non-athletes do, especially endurance athletes. Coyle indicates that water loss can be 1-2 L per hour during prolonged exercise with runners drinking 0.3-0.5 L per hour.⁷ Murray recommends drinking 24 oz of water at intervals before exercising, 4-8 oz every 15-20 minutes during exercise and at least 16 oz afterwards.⁸

Table 8. Water Consumption Patterns for Adults

Date: sample size	May: 32	October: 84
Mean:	3.79 liters / day	1.79 liters / day
Median:	1.51 liters / day	1.51 liters / day
Female mean		1.90 liters / day
Male mean		1.63 liters / day
Range: 0.2—9.2 liters per day		

Source: Woltemade, personal communication

Table 9. Shows water consumption rates for young children. The consumption rates are less than for adults but also show considerable variability.

Table 9. Water Consumption Rates of Young Children

Age	Percentage	Range (oz)	Mean Total water intake (oz)
6 weeks	28	0—42	14
3 months	24	0-48	19
6 months	42	0-38	17
9 months	66	0-59	16

Source: J Dent Res 74(7):1399-1407, July 1995

Estimated fluoride consumption data and recommended ranges for young children using data from Levy et al. is shown in Table 10.⁹ This is shown graphically for six and nine month olds in Figure 2 and Figure 3. Approximately 10-12 percent of six and nine month olds receive the optimum dose from water. Thus it is clear that dosage is difficult to constrain to the proper amount from water fluoridation alone, much less taking in to account the variability from diets.

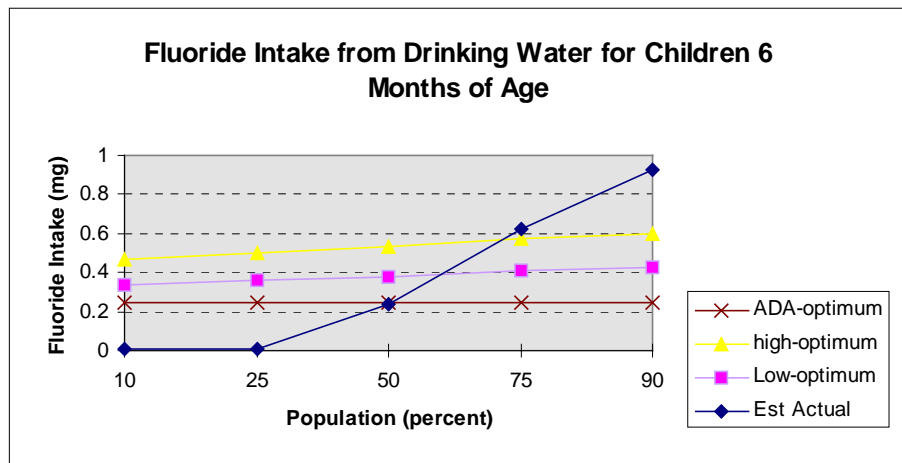
It is clear that fluoride intakes from water vary greatly. This is true for adults and children alike. For adults, the data show daily consumption ranging from 0.2-9.2 L. This suggests that fluoride from water consumption could vary by a factor of 46. The highest water-consuming adult would receive over six times as much fluoride from water as an individual consuming the median amount of water. Water fluoridated at the higher end of the “optimal range” (1.2 PPM fluoride) could result in daily fluoride consumption of 10.8 mg of fluoride (excluding fluoride consumed in the daily diet). This rate of fluoride intake is almost 11 times higher than the highest recommended daily dose and in the range associated with probable health hazards.

Military personnel must meet physical conditioning requirements. This suggests they would exercise more (and thus drink more water) than the general population. Spouses and children, however, are probably in line with general population. This suggests more variability in per person water consumption patterns on military installations than in the general populace.

Table 10. Fluoride Intakes from Water for Six Month Olds

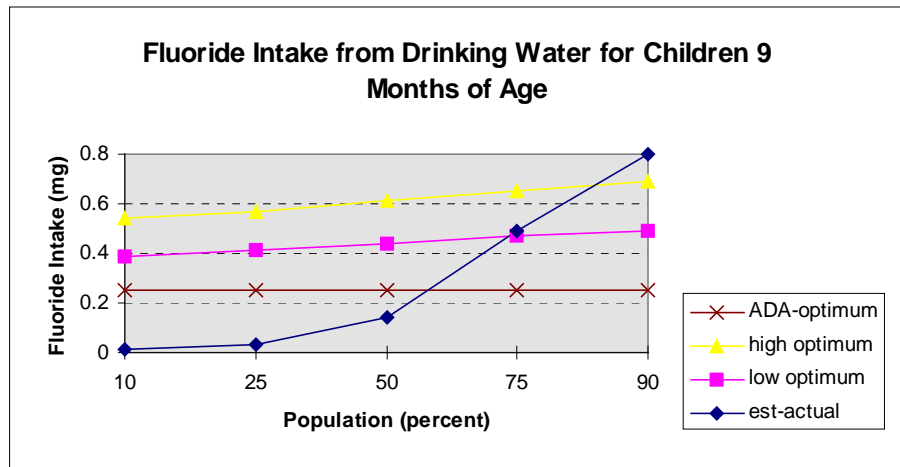
Percentile	Estimated Actual	6 months	
		Optimum FI Low	Optimum FI High
10	0.01	0.34	0.47
25	0.01	0.36	0.5
50	0.24	0.38	0.53
75	0.62	0.41	0.57
90	0.93	0.43	0.6

Source: Levy et al., Journal of Dental Research, 1995.



Source: Adapted from Levy et al. (1995) and ADA

Figure 2. Supplemental Fluoride Dose v. Optimal Recommended Range



Source: Adapted from Levy et al. (1995) and ADA

Figure 3. Supplemental Fluoride Dose v. Optimal Recommended Range

Delivery Effectiveness

To be effective, the supplemental fluoride must be consumed. In the case of water fluoridation, the water itself must be consumed. Thus the effectiveness of water as a delivery system for supplemental fluoride requires determining who consumes the water.

To determine the population that consumes the water requires evaluating access to the water (that is who is served by the fluoridated water system) and what percentage of their water is consumed from that source. The typical method is to simply cite the number of persons that live on the affected water system. This would severely underestimate the number of potential beneficiaries in this case. To avoid this, the number of persons that reside, work, or attend school in areas of Kadena served by the fluoridated water supply system are estimated and water consumption is apportioned therein.

The exact number of personnel assigned to and residing on Kadena varies on a daily basis. It does not, however, vary greatly over time due to a fixed number of housing units being available. In 1995 there were (all services) just under 13,700 total families members living in Kadena's

MFH.¹⁰ As shown in Table 6, there were 13,255 family members living in Kadena's MFH, and 1,895 unaccompanied individuals living on Kadena.

The number of children on base can be estimated by assuming the number of single parent families equals the number of families having adult dependents (e.g., grandparents) living with them. Based upon this assumption there are approximately 5,670 children in Kadena's MFH. Norda estimated that there were 5,727 children living in Kadena MFH in 1995.¹¹

Chibana and O'Donnell Gardens housing areas are considered part of Kadena base housing but are geographically separated from Kadena and have separate water supply systems. Together these two areas have 579 family housing units. The average density is 1.18 persons per bedroom. Using this, the previous assumption of two adults per housing unit, and factoring in a pro-rata share of vacant units suggests there are about 1,050 children living in Chibana and O'Donnell Garden. Norda estimated approximately 1,150 children in 1995.¹² Thus there are approximately 4,620 children and 8,350 adults living on areas served by Kadena's water system.

The following is based upon the above information and assumes a linear distribution by age for those under 18 years of age. It appears that the population living on Kadena consists of approximately 130 infants less than six months of age (under the recommended age range for supplemental fluoride), 3,980 children between the ages of six months and 16 years (recommended recipients), and 8,470 persons above 16 years of age (potential beneficiaries).

In 1995 there were 9,878 children that attended an on base school. There were 201 students classified as tuition paying students. This leaves 9,677 dependent children or 800 children per age group. Approximately half of these children attend school on Kadena. Children attending school on Kadena but not living on Kadena should receive partial benefits from Kadena's

fluoridated water. These children also come on base for reasons other than school attendance. These children probably receive 30 percent of the benefits from a fluoridated water supply.

There are approximately 1,060 children that do not live on Kadena but do attend school on Kadena. Assuming a 30 percent benefit for these children results in 320 additional full time equivalent (FTE) children in the recommended age range. Thus we have a maximum of approximately 4,300 FTE children in the recommended age range for fluoride supplements. It is unknown how many children attend daycare on Kadena that would also benefit but the 4,300 should be a reasonably accurate estimate of the total.

There are approximately 2,170 adults working on Kadena that live on other bases or live off base. Assuming 45 percent benefits for these adults this equates to about 975 additional FTE potential beneficiaries. Adding 10 percent for the other 2,170 adult family members adds 215 for a total of approximately 1,190 additional FTE potential beneficiaries.

The number of FTE beneficiaries is now identified. There are approximately 130 infants below the recommended age for fluoride supplements (under six months), 4,300 FTE children that are in the recommended age range for supplements (six months to 16 years), and 9,660 FTE potentially benefiting persons above 16 years of age.

There is a large bottled water consuming population on Okinawa. Bottled water consumption by US personnel with access to the Commissaries and the Army Air Force Exchange System (AAFES) exceeded 4,617,381 liters per year for 1998 (note: excludes bottled water purchased locally by individuals or for resale).¹³ This equates to 3,057,868 person-days or 8,377 person-years of bottled water consumption based upon the median water intake of 1.51 liters per person per day. It is assumed that 10 percent of this water is used for cooking. This suggests that approximately 7,500 person years of drinking water are replaced by bottled water.

Water off base is exactly the same quality as water on base and comes from the same sources. Thus there is no reason to assume that those living off base drink any more or any less bottled water than those living on base. Applying this and 1997 population data it is estimated that 14 percent of the total population consumes bottled water.

The total number of probable beneficiaries can be calculated by applying this 14 percent across the board. This suggests that the probable number of FTE recommended beneficiaries (children between six months and 16 years of age) is approximately 3,700 and there are approximately 8,310 FTE potential beneficiaries over 16 years of age.

There are approximately 13,300 DOD related children in the recommended age range (six months to 16 years) for fluoride supplements. Fluoridating Kadena's water will benefit approximately 3,700 FTE children representing 28 percent of the possible 13,300 children within the recommended age range. Fluoridating Kadena's water will reach additional 8,310 FTE potential beneficiaries (those over 16 years of age) representing 19 percent of the 43,230 persons that are potential beneficiaries.

System Costs

Kadena does not have its own internal water treatment plant. Instead, the base buys potable water from near by cities. Potable water enters Kadena from both Ishikawa and Chatan water treatment plant. One line enters near Gate 2 and goes to an above ground water tank farm while the line entering near Gate 3 goes to in-ground tanks at Ty-base. To treat all Kadena water requires two water treatment systems.

Table 11 shows the variety of cost estimates made with respect to fluoridating Kadena and the final actual estimated costs. The system recommended by Detachment 3, Armstrong Laboratory, (Det 3) used sodium fluoride.¹⁴

Table 11. Estimated Water Fluoridation Startup and Operating Costs

Who	Estimated Start-up Costs	Estimated Annual Costs	Source
18 DS & 18 MDG	\$35,000	\$15,000	(1995) Staff Summary Sheet
18 DS & 18 MDG		\$0.51 /person	(1996) Staff Summary Sheet
18 DS & 18 MDG	\$80,000	\$15,000	(1996) Staff Summary Sheet
18 CES / 718 CES	+\$200,000	\$50,000	(1996) Rough Estimate
Detachment 3	\$265,000	\$40,000*	(1997) Consultative Letter
Contract Award	\$292,500	unknown	(1997) 718 CES
Estimated Final Cost	\$310,000	see below	Award plus 6% oversight

*Detachment 3 estimate did not include total labor costs (salary + benefits).

Table 12 shows a break out of the estimated annual costs for fluoridating Kadena's water supply. The first column shows the actual Det 3 estimate. The second column shows modifications made to better estimate the actual costs.

Table 12. Estimated Annual Operating Costs

Expense	Det 3	Modified Estimates
Manpower (direct)	\$16,000	(total) \$23,250
Chemicals	\$22,000	\$22,000
Maintenance	\$2,000	\$2,000
Supplies	\$200	\$200
Environmental expenses		\$800
Total estimated expenses	\$40,000	\$48250

Source: Det 3 Consultative letter with modifications

The original Det 3 manpower included only the base salary and failed to include benefits. Benefits account for approximately 1/3 of the salary for local national employees. In addition, no costs were assigned for environmental factors such as disposal of spilled chemicals, compliance audits or inspections (e.g., Environmental Compliance and Assessments Management Program).

According to Kadena AB Public Affairs, there are 13 significant installations on Okinawa.¹⁵ The contract to install the two units at Kadena is about \$292,500. The water at Camp Lester is already fluoridated. Chibana and O'Donnell Gardens have their own separate water supply

systems. Thus at least 13 additional fluoridation systems are required island wide. Based upon the actual costs for Kadena, installation costs alone would exceed \$2,000,000 dollars to fluoridate these 13 water systems (at one unit per location).

Several of the satellite systems would require less chemicals but require more time to drive to each day to check and maintain. Thus the overall annual system costs are probably similar. For 13 additional systems the annual maintenance costs would exceed \$600,000 annually. This is over \$10 per DOD person per year in maintenance expenses alone.

The pumps, mixing equipment, and feeder systems will probably require replacement every five years as the environment on Okinawa is quite harsh on mechanical equipment. Assuming equipment replacement costs are \$58,000 every 5 years and a 30-year life on the building and facilities, we get an annualized capital cost of \$20,500 per year for Kadena (no inflation). Adding in the \$48,250 in maintenance costs and the total annualized cost is approximately \$68,800 per year for just Kadena. This equates to \$18.60 per year per benefiting child or \$5.70 per year per FTE beneficiary.

The annual carie development rate as shown in Table 1 is about 0.4 caries per year. For children between six months and 16 years of age, a 25 percent reduction amounts to 0.1 caries avoided annually per full time beneficiary. This equates to preventing 370 caries per year in children. For those over 16 years of age, a 15 percent reduction prevents 0.06 caries annually per full time beneficiary. This equates to avoiding 500 caries per year for adults for at total of 870 caries prevented. The cost is \$79 per avoided carie.

Other Considerations

Kadena's water usage varies annually depending upon time weather conditions. The average consumption rate is approximately 4.5 million gallons per day.¹⁶ Using a sodium fluoride feed

system to achieve 0.7 PPM equates to a feed rate of 59.2 pounds per day. This is 21,600 pounds (LB) of hazardous chemicals used and released in to the environment annually. Increasing the use and release of hazardous materials into the environment conflicts with the Pollution Prevention Act, Resource Conservation and Recovery Act, Executive Orders (e.g., 12856 and 12873), DOD Directive 4715.1, DOD Instructions 4715.4 and 4715.6, Air Force (AF) Instruction 32-7080, AF Policy Document 32-70, and the AF Pollution Prevention Strategy. DOD Directive 6230.1 states installations with children in residence will adjust fluoride “ in conformance with accepted health practices.”¹⁷ Accepted health practices, per the Environmental Protection Agency (EPA), is that drinking water should contain less than 2.0 PPM of fluoride. Japanese law may supersede it – Japan does not fluoridate its water.

There is currently an emphasis on force protection within DOD. Water fluoridation may increase the risk to forces as it provides an additional point of access to easily inject poisons or other chemicals directly into the water system.

Notes

¹ Review of Fluoride Benefits and Risks, Department of Health and Human Services, 1991.

² America Dental Association, Fluoride Facts: Public Policy, available from www.ada.org/consumer/fluoride/facts/ff-04.html.

³ American Water Works Association Manual of water supply practices - AWWMA M4 p11

⁴ Ibid page 20. (AWWAM M4 page 20)

⁵ Academy of General Dentistry, Fact Sheet, November 1994.

⁶ Christopher Woltemade, Personal Email, based upon “Drinking water consumption rates and associated dietary magnesium and calcium in Shippensburg, PA” by Heather Stahlnecker et al., presented at the 1998 Pennsylvania Academy of Science Annual Meeting, Pittsburgh, Pennsylvania.

⁷ Edward E. Coyle, “Fluid and Carbohydrate Replacement During Exercise: How Much and Why?,” Sports Science Exchange #50 7, no. 3, (1994), available at <http://veggie.org/run/fluid.exercise.html>.

⁸ Healthy Ideas, “Body Buzz - Are You Drinking Enough Water”, available at www.healthyideas.com/weight/buzz/980805.buzz.html.

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⁹ S. M. Levy et al., “Infants’ Fluoride Intake from Drinking Water Alone, and from Water Added to Formula, Beverages, and Food”, *Journal Dental Research* 74, no. 7 (July 1995): 1399-1407.

¹⁰ Personal notes, work by Jeff Norda, based upon 1995 Marine Housing Report.

¹¹ Ibid Norda

¹² Ibid Norda

¹³ Peter Conrady, Special report on DeCA water sales in Okinawa for 1998 undated, and Marilyn Tarin, email, AAFES water sales Dec 1997-Nov 1998, 4 Jan 1999.

¹⁴ Det 3, Armstrong Laboratory (AFMC), “Consultative Letter (CL), AL/OE-CL-1997-0004, Kadena AB Fluoridation System,” 31 January 1997.

¹⁵ Kadena AB website, <http://www.kadena.af.mil/current/18pa/welcome.htm>

¹⁶ Det 3, Armstrong Laboratory (AFMC), “Consultative Letter (CL), AL/OE-CL-1997-0004, Kadena AB Fluoridation System,” 31 January 1997.

¹⁷ Department of Defense (DOD) Directive 6230.1. Safe Drinking Water, 24 April 1978.

Chapter 5

Fluoride Enriched Salt

Fluoride enriched salt is the preferred method of many nations to provide supplemental fluoride. It is currently used in Germany, Switzerland, France, Uruguay, Bolivia, Colombia, Ecuador, Peru, Venezuela, Spain, Hungary, Costa Rica, and Jamaica.¹ In 1991 Mexico abandoned its water fluoridation efforts and switched to fluoride enriched salt.² There are approximately 50 million people that receive supplemental fluoride via fluoridated salt.³

The process of fluoride enriched salt is similar to that of iodized salt. Iodized salt has been practiced for 70 years to prevent iodine deficiency disorders (e.g., goiter, and mental retardation). It has been extremely successful. “By 1930, much of the salt consumed in America was iodized, and by 1951, goiter had largely disappeared from the US.”⁴ The program has also been successful worldwide.

The process of fluoride enriched salt is very simple. The manufacturer adds fluoride at the plant to the salt, packages it, and delivers it to retail outlets for purchase by consumers. Since the manufacturer carries out the process, there is no effort imposed upon using areas or consumers as the consumers already have to go to grocery stores or the Commissary. Bergman sums this up nicely by stating that “Salt fluoridation is a systemic form of fluoride supplementation, leaving it to the consumer whether he wants fluoride supplements or not, but thereafter not requiring special dependability for daily compliance.”⁵

Effectiveness

According to the American Dental Association “Fluoridated salt comes second to drinking water as a dietary vehicle for ensuring adequate intake of fluoride.”⁶ In addition the American Dental Association writes:

Based on several studies comparing fluoridated salt with fluoridated water, it appears that the caries-preventive effectiveness of fluoridated salt is substantial and therefore, it may be an adequate alternative, especially for parts of the world which do not have many communal water supplies.⁷

These finding are supported by findings by Hescot who found that DMF rates for children in France decreased from 4.2 in 1987 to 2.07 in 1993, a reduction of 50 percent.⁸ It is unknown if this was a double blind or scientifically defensible study. However, the findings here, and the endorsement (albeit reluctantly it appears) of the American Dental Association, make it clear that fluoridated salt is approximately as effective as fluoridated water. For the purposes of this study this will be assumed true.

Dose Control

The dose of fluoride from fluoridated salt also depends upon the concentration and volume consumed. Typically potassium fluoride is added to the salt in concentrations of approximately 250 PPM.⁹ No data was found reflecting the actual variance of concentration of fluoride in salt. Hescot indicates a tolerance of plus or minus 15 percent around the value of 250 milligrams per kilogram (equivalent to 250 PPM).¹⁰ Estupinan-Day indicates that 250 PPM plus or minus 50 PPM has good carie prevention effects and does not result in fluorosis.¹¹ Over all, both of these ranges are tighter than the 0.7 to 1.2 PPM “optimum” range given for water fluoridation. No further analysis can be made. It is tempting to assume that fluoridated salt concentrations would be tighter due to manufacturing concerns but this would be unsupported conjecture.

Data regarding salt consumption ranges was surprisingly difficult to locate. According to the Salt Institute the “The very large percentage of the population consumes 1,150- 5,750 mg/day which is termed the “hygienic safety range” of sodium intake by renowned Norwegian hypertension expert Dr. Bjorn Folkow.”¹² This data is for sodium but the range would be similar for salt. One source found that salt consumption in temperate climates is 5—8 grams per day.¹³ Thus it appears that for the majority of the population the salt consumption varies by a factor of about five. This is in agreement with data from the National Health and Nutrition Examination Survey (NHANES) shown in table 13.¹⁴

Table 13. Total Salt intake

Quartile	Male Na mean intake (mg)	Male Std Dev	always /never	Female Na Mean intake (mg)	Female Std Dev	always/ never
Q1	1041	322	34 / 46	678	229	20 / 57
Q2	1832	195	39 / 35	1232	138	22 / 57
Q3	2647	282	37 / 36	1791	196	25 / 53
Q4	4538	1489	46 / 32	3105	1002	30 / 47

Source: M. Alderman, H. Cohen, S. Madhavan, “Dietary sodium intake and mortality: the National Health and Nutrition Examination Survey,” *Lancet* 14, no. 351 (March 1998): 781-5.

Clearly there is variability in salt consumption. The variability in total salt consumed varies by a factor of about 5. Variability appears to be narrower than for water fluoridation but this can not be claimed for certain. No age related salt consumption data was found.

Delivery Effectiveness

The effectiveness of the delivery system would be unsurpassed by any other method as all DOD related personnel on Okinawa have access to the Commissary. This means that fluoridated salt would be available to 100 percent of the 55,000-56,000 personnel on Okinawa. This far exceeds the potential for any other method.

Data in Table 13 show that 55 percent of the adult population routinely uses salt. This would equate to approximately 23,780 persons over 16 years of age or 30,410 persons above six months of age. It is likely that the actual number is between these two and somewhat closer to the higher number since children would consume food prepared at home.

One limiting factor is the use of salt and the willingness to purchase fluoride enriched salt. It might be possible to increase the number of consumers if a low or no sodium fluoride enriched salt were available.

System Costs

There would be no required annual expenditure of appropriated funds to implement the use of fluoride enriched salt as a method of providing supplemental fluoride. For a cost of less than \$100 per year the bases could add this information to all newcomer and welcoming briefings and publish an article in the base papers quarterly.

The Commissary has existing procedures for new products to be added to local Commissaries. Thus there would be no need for any process changes or modifications.

It is unknown how much fluoridated salt would cost the consumer but it is likely to be only a very few cents per pound of salt. Iodized salt generally runs one to three cents higher per pound and this is a likely range for fluoride enriched salt. Some countries control the price of salt to keep the cost of fluoridated and non-fluoridated salt the same.

Other Considerations

There appears to be no environmental concerns with respect to fluoride enriched salt. Any fluoride entering the environment unused would be minor. The low level of fluoride in the salt

would prevent the salt from being a hazardous material. In fact, this would actually appear to be an excellent pollution prevention initiative.

Salt has garnered a bad reputation due to being associated with hypertension. There is considerable variability in the literature with some studies showing significant increases in blood pressures while other find the opposite. Even more confounding is that the studies are not repeatable. That is, the same subjects will not respond exactly the same during repeat trials.

Many physicians recommend reduced salt consumption and that salt consumption levels be in the 2500 mg per day level. This recommendation was a consensus estimate that is unsupported by any studies. The theory was that reducing salt consumption would reduce high blood pressure which would in turn reduce cardiovascular disease.¹⁵

Alderman et al. used 24-hour urinary excretion of sodium data and compared this to Myocardial infarctions.¹⁶ This study found an inverse relationship between myocardial infarctions and sodium intake for men and no statistically significant difference for women. The researchers point out that their study does not support the universal recommendation to reduce salt consumption.

Other studies also refute the recommendation to universally reduce salt consumption. These studies have found low-sodium diets to increase fatigue, worsen sexual physical problems among men, and increase adverse effects on sleep for men.¹⁷

Notes

¹ Saskia Estupinan-Day “Proposal to the W.K. Kellogg Foundation.” Pan American Health Organization, May 1996.

² Dra. Lucila Hernandez, (National Coordinator of the Salt Fluoridation Program in Mexico) Online. Internet. Obtained from blake.oit.unc.edu/health/english/newsletter/n3/prevent.html (1/13/98) (blake.oit.unc.edu site no longer accessible)

³ World Health Organization Press Release, 15 February 1994.

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⁴ David Alnwick, "Solving iodine deficiency." On-line. Internet. Available from www.kiwanis.org/wsp/iddsolv.htm, dated 13 Dec 1995.

⁵ Bergmann KE, Bergmann RL, Adv Dental Res 1995 (Pubmed abstract)

⁶ American Dental Association. On-line. Internet. Available from <http://www.ada.org/consumer/fluoride/facts/ff-02.html#10>

⁷ Ibid.

⁸ Dr. Patrick Hescot, President of UFSBD (French Union for Oral Health), "Fluoridated Salt: A Measure of Public Health in France." Obtained from CEDROS website (1996), reprints available from French Union for Oral Health.

⁹ Saskia Estupinan-Day, "Multi-Year Plan for Salt Fluoridation Programs in the Region of the Americas Bolivia, Dominican Republic, Honduras, Nicaragua, Panama, Venezuela," a Pan American Health Organization Proposal to the W.K. Kellogg Foundation dated May 1996.

¹⁰ Dr. Patrick Hescot, President of UFSBD (French Union for Oral Health), "Fluoridated Salt: A Measure of Public Health in France." Obtained from CEDROS website (1996), reprints available from French Union for Oral Health.

¹¹ Saskia Estupinan-Day, "Multi-Year Plan for Salt Fluoridation Programs in the Region of the Americas Bolivia, Dominican Republic, Honduras, Nicaragua, Panama, Venezuela," a Pan American Health Organization Proposal to the W.K. Kellogg Foundation (May 1996): 8.

¹² "Medical Questions Regarding Dietary Salt" available from <http://www.saltinstitute.org/28.html>.

¹³ M. G. Venkatesh Mannar, and John T. Dunn, "Salt Iodization for the Elimination of Iodine Deficiency." Copyright International Council for Control of Iodine Deficiency Disorders, 1995. On-line. Internet, 20 March 1999. Available from <http://avery.med.virginia.edu/~jtd/iccid/iodman/iodman4.htm>.

¹⁴ M. Alderman, H. Cohen, S. Madhavan, "Dietary sodium intake and mortality: the National Health and Nutrition Examination Survey," *Lancet* 14, no. 351 (March 1998): 781-5

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Chapter 6

Findings and Conclusions

The previous chapters discussed the importance of good dental health for the military. The role fluoride plays in furthering good oral health was identified. Two methods of providing supplemental fluoride in overseas locations, water fluoridation and fluoridated salt, were examined. The following section summarizes findings regarding the two methods.

Findings

Fluoridated water and fluoridated salt are widely used methods of providing supplemental fluoride. Both methods are effective in reducing dental caries. Fluoridated salt appears to have many advantages over fluoridated water for application in Okinawa. These are discussed below.

Effectiveness

The effectiveness of fluoride in preventing caries is similar regardless of the method provided. The mechanisms are the same. Estimated effectiveness is 15 and 25 percent for children and adults respectively and accounts for the trend of decreasing caries over time.

Dose Control

There is considerable variability in the dose of fluoride delivered by each method. Fluoride concentrations in Melbourne's water varied by 50 percent (during the period the system worked) and ranged from 0.657-0.995 PPM. No fluoride was provided for 139 consecutive days.

No data was found showing the variability of fluoride concentrations in salt. Thus no conclusion can be asserted.

Data regarding water consumption habits was limited. Water consumption by children less than nine months of age ranged from 0-59 oz. Children drinking the mean amount of water (0.5 L) with 0.7-1.2 PPM of fluoride receive 0.35-0.57 mg of fluoride. Those in the upper range would receive 1.3-2.1 mg of fluoride or 520-840 percent of the ADA recommended amount. Few, very young children receive the recommended dose of fluoride.

Data regarding water consumption for adults was also scarce. Variance data (e.g., standard deviation) was unavailable. Reported water consumption rates ranged from 0.2-9.2 L with a median of 1.5 L. Adults drinking the mean amount receive 1-1.8 mg of fluoride or up to 80 percent more than the highest ADA recommended dose for any age group. Adults near the upper limit receive 640-1100 percent more fluoride than the highest recommended ADA dose.

There was limited data available regarding salt consumption. No age related data was found. Daily salt consumption for the majority averaged 0.9-3.8 grams. If all salt consumed was fluoridated with 250 PPM of fluoride the majority of the population would consume 23-95 percent of the highest dose recommended by the ADA for any age group.

Delivery Effectiveness

The delivery effectiveness of water fluoridation at Kadena is quite limited. A large DOD related population lives in areas not served by Kadena's water system. Fourteen percent of the population consumed bottled water. In addition, the 3-18 month waiting period means many persons will receive limited or no fluoride benefits for up to half of their time on island.

Water fluoridation will provide FTE benefits to 28 percent or 3,700 of 13,200 children between six months and 16 years of age and prevent 370 caries annually. FTE benefits would accrue to 8,310 of 43,230 (19 percent) of those over age 16 and prevent 500 caries annually.

Fluoridated salt could provide FTE benefits to 50 percent or 6,630 children between six months and 16 years of age and prevent 660 caries annually. FTE benefits would accrue to 23,780 adults and prevent 1,430 caries annually.

System Costs

The cost to Fluoridate Kadena's water system is \$310,000. Operating costs and life cycle costs are estimated to be \$48,250 and \$68,800 annually. Estimated cost per carie avoided are \$55.50 and \$79 based on operating costs and life cycle cost respectively. Fluoridating all DOD systems on Okinawa would cost \$2,000,000 with operating costs exceeding \$600,000 annually.

A fluoridated salt program would carry little or no cost to the government. The primary cost would be in letting the population known about the product. This could be accomplished for free in the base papers or for about \$100 if included in newcomer packages. The estimated cost to beneficiaries is less than \$0.05 per pound of salt

consumed or less than \$0.15 annually. The estimated cost per avoided carie (regardless of installation) is \$2.50.

Other Considerations

Fluoridating Kadena's water will result in the annual release of 21,600 pounds of hazardous chemicals in to the Okinawan environment. It also conflicts with environmental laws, regulations, and policies. There is no conflict with DOD Directive 6230.1 if the water is not fluoridated. This directive requires fluoride levels be adjusted to meet good health practices. This requirement is met if fluoride levels are in the 0-2.0 PPM range (EPA health standards).

Housing is already at a premium on Kadena. Fluoridating Kadena's water may increase desirability of Kadena's housing and reduce desirability of other locations. This would increase the time families live off base while waiting to move on base.

Another significant concern involves force protection issues. Each fluoridation unit provides another access point for terrorists. It would not be difficult for terrorists or vandals to gain entry and then have easy access to meddle with the water supply system.

A salt fluoridation initiative may increase salt consumption. Increased salt consumption by salt sensitive persons with high blood pressure is undesirable. Medical professionals were recommending reduced salt consumption for everyone. Recent data suggest this may be unwise. However, those that followed this advice may hesitate to return to routine use of salt.

Conclusions

Good oral health is important to our military. Poor oral health can have adverse impacts on troop readiness and performance. Maintaining good oral health will become more important as the military force structure continues to shrink. This decrease in available personnel means that losing personnel due to preventable health problems, such as caries, will become unacceptable.

This study suggests that fluoridated salt is the preferred method of providing supplemental fluoride to DOD personnel located on Okinawa. This research suggests there are many benefits to implementing a fluoridated salt program in lieu of fluoridating Kadena's water. These benefits are summarized as follows:

1. Fluoride available to all DOD personnel regardless of geographical location or water source and on arrival to Okinawa avoiding the 3-18 month wait for on base housing.
2. Potentially increases FTE's by 250 percent and reduces 1,220 more caries annually.
3. Less probability of children under the recommended age being dosed with fluoride
4. May provide a tighter overall dose control with less risk of severe over dosing and has less potential for overdosing of large segments of the population simultaneously.
5. Can be implemented at no cost, operated for \$100 per year and save \$48,250 annually
6. Cost per avoided carie is reduced from \$79 for water fluoridation to \$2.50
7. Complies with all known laws, regulations and policies and avoids the purchase and release of 21,600 pounds of hazardous chemicals annually.
8. Does not carry increase force protection concerns.

In summary, this study suggests that selling fluoridated salt in the Commissary would be the most efficient, most effective, least costly, and most equitable method of providing supplemental fluoride to DOD personnel on Okinawa. It would prevent more caries and improve oral health better than any other mass fluoridation alternative.

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